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YIELD, WATER PRODUCTIVITY AND ECONOMICS OF VEGETABLE PRODUCTION UNDER DRIP AND FURROW IRRIGATION IN EASTERN PLATEAU AND HILL REGION OF INDIA

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ABSTRACT

An experiment was conducted on evaluation of drip and furrow irrigation methods in participatory mode at the farmer's field with an aim to develop understanding about potential benefits of drip irrigation system among the tribal farming community of the eastern plateau and hill region. Comparative assessment in terms of yield gain, water productivity (WP) and net returns was carried out for tomato, potato, cauliflower, french bean and pea cultivated in the farmers' fields at Saraitoli village of Ranchi district of Jharkhand. The study revealed that, for the selected vegetables, adoption of drip irrigation improved the yields in the range of 38.2 to 65.8 % over furrow irrigation with highest yield increase in case of pea (65.8%) and tomato (58.7%). Drip irrigation consistently recorded higher water productivity (WP) with more than five folds increase in case of potato and cauliflower. The average WP was higher under drip irrigation (6.89 kg m-3) as compared to furrow method (1.31 kg m-3). Economic analysis revealed that the average cost-benefit (CB) ratio of all drip irrigated crops was about 33% higher over furrow method of water application. Among all the crops drip irrigated cauliflower was found to be the most remunerative crop with higher net returns (1,98,336Rs.ha-1) and highest CB ratio of 2.98. The comparative economic analysis of drip and furrow irrigated crops presented in this study will assist the farmers in crop selection. Precise use of water with better productivity and higher net returns from the drip irrigated vegetable crops motivated the farmers to adoption drip irrigation technology.

***KEYWORDS:** Drip Irrigation, Furrow Irrigation, Yield, Water Productivity & Benefit-Cost Ratio*

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Original Article

INTRODUCTION

The state of Jharkhand with large population of tribal farming community is often characterized with low production and productivity of horticultural crops. The traditional cultivation practices lead to below average productivity of many horticultural crops. Water scarcity is the critical constraint that precludes the tribal farmers from cultivation of vegetables crops during the dry season (*Rabi* and Summer). The main source of income of the tribal farmers is agriculture and almost 66% of the total populations of Jharkhand depend upon agriculture. Land use statistics suggest that in spite of large cultivable area (52%), only 22% is under cultivation which is below the national average of 47% (Petare, 2016). Agriculture is predominantly rain fed and mono-cropped in Jharkhand. Horticulture is marginally developed in the tribal areas with the present area under fruits, vegetables and spices accounting for only about 2.5% of the cultivated area. The major constraints in the area are steep slopes with undulating topography, severe water erosion and low water holding capacity of soils. Erratic rainfall, lack of irrigation facilities, poor water retentive capacity and high permeability of the soils are the major problems limiting successful double-cropping.

Promoting use of water efficient technologies for better utilization of available water resources to increase the productivity and acceptance of horticultural crops in these areas was a major challenge. In general, traditional flood irrigation methods (basin, border and furrow) are being used, where the entire soil surface is almost flooded without considering the actual consumptive requirements of the crops. Frequent over or under irrigation create the problems of water stress or water logging leading to reduced irrigation efficiency (<30 %) (Ishfaq, 2002). This highlights the need to adopt modern efficient irrigation method of drip which offers several advantages over furrow irrigation including higher water and fertilizer use efficiency and high yield (Camp *et al*., 2001).

Drip irrigation method applies water and nutrient directly to the root zone of plants (Sharma, 2001). Its major advantages as compared to other methods include higher crop yields, saving in water, increased fertilizer use efficiency, reduced energy consumption, reduced labor cost, improved diseased and pest control and feasible for undulating sloppy lands (Michael, 2008). In a study Yildirim (2000) also reported that drip irrigation generally achieves better crop yield and balanced soil moisture in the active root zone with minimum water losses. On the average, drip irrigation saves about 70 to 80% water as compared to conventional flood irrigation methods (Camp *et al*., 2001).

Many researchers have proved the superiority of drip irrigation over other conventional method of irrigation in improving yield and WP of fruits and vegetable. There are very few studies that looked in to all the economic aspects of drip systems with the aim of promoting the system among tribal farmers. Participatory evaluation of this technology in farmers' fields will not only demonstrate the potential benefits of the technology to farmers but will also help in assessing the ground realities and problems faced by the farmers in large scale adoption of this technology. The present study made a comparative evaluation for drip and furrow methods of water application in terms of yield and WP. The study further extends to economic analysis of these systems with the aim of convincing the farmers about the profitability of drip irrigation.

MATERIALS AND METHODS

Study Area

The present study was carried out in Saraitoli village located in Ranchi district in eastern plateau and hill region of India where water is one of the main constraints in adopting the vegetable crops. The annual rainfall in the plateau and sub-plateau region is 1400 mm, on an average of which 82.1 % is received during June to September. Rest of the period remains dry and crop production is difficult in rest of the time. Only about 9 percent of the area in the State is irrigated. The low availability of water has forced many farmers to restrict to mono cropping. The soil of the study area belong to the order 'Alf sols' having sandy loam to loamy texture. The pH of the soil varied from 5.5 to 6.0, organic carbon content 0.35-0.45 %, and available N and K at low to medium status. The soils are low in available phosphorous.

Training for Capacity Building of Farmers

The participatory evaluation program started with initial sensitization and demonstration of potential benefits of the drip technology to farmers through audio-visual aids and through field visits to research farms having operational drip systems. The hands-on-experience type of trainings were conducted for the farmers to get them the fill of the technology. With this background, some farmers agreed to adopt this technology in their fields while some restricted themselves to traditional furrow irrigation system. The drip systems were designed and installed in participatory mode. Involvement of farmers in installation further widened their knowledge about the system and they also learnt to tackle minor repairs of the

system. Ten farmers among the 25 farmers who adopted drip irrigation technology were selected for the study. Another ten number of farmers who followed the traditional furrow system of planting were selected for comparative evaluation. Irrigation timings and pump discharge data were noted for each irrigation event to work out the seasonal amount of water applied to each crop.

Methods of Water Application

The drip system consists of 110 mm PVC pipe mainline connected to 63 mm PVC pipe sub- main line, which was connected to 16 mm Jain Turbo Type lateral line with 2.4 lph inline drippers spaced at 40 cm. The distance between row to row and plant to plant was kept 1.0 m and 0.4 m, respectively. The laterals were laid on the ground surface along the lines of plants. Uniformity of water application in the farmers' fields was ascertained by measuring the discharge from individual emitters for a specified time period. In furrow irrigation system, furrows and ridges were prepared by farmer with the help of spade. The top width of ridges was 60 cm while that of furrows was 40 cm. The row to row and plant to plant distance was same as in drip irrigation. After the preparation of land, composite soil samples were collected at 0-15 cm depths for the determination of available nutrients at the beginning of the cropping season. All the agronomic and crop management practices like fertilizer application, plant protection measures were same in both the methods. In case of all the crops, same variety was cultivated as per the farmers' practices. In case of drip system the irrigations were scheduled on the basis of consumptive use of crop (ETc) as estimated using the average weekly pan evaporation data as suggested by Allen (1998). Irrigations were scheduled at one day interval for drip system while under furrow system, farmers' practice of irrigation (7 day interval) was followed.

Data Collection and Analysis

Plot specific data collection sheets were designed to record the manpower and other inputs used throughout the cropping season. The plot wise data on labor requirement and other expenditures on land preparation (plowing, harrowing, bed preparation), plant protection measures, irrigation, staking, harvesting etc. was recorded in the designed sheets. Cost of drip irrigation system was calculated at prevailing market prices of the drip system installed in the field (Jain irrigation systems ltd.) without any government subsidy. Market prices of the selected vegetables were recorded for entire harvesting period to estimate the gross returns. The seasonal cost of growing vegetables under drip fertigation was calculated by considering depreciation, life of components, seasonal interest, fertilizers, insecticide, labors and cost of cultivation of growing vegetables. For seasonal cost of drip irrigation system, working life of drip irrigation components i.e., main line, sub main, fertilizer tank, venturi assembly and filters was considered as 12 years and for laterals with inline emitters considered working life was 5 years. The net profit and BC (BC) ratio was calculated for both the methods of irrigation. The yield, water productivity, net returns and BC ratio was statistically analyzed using analysis of variance (ANOVA) at 5% level of significance.

RESULTS AND DISCUSSIONS

Yield and Water Productivity

Results of the yield and water productivity of different vegetables as obtained under drip and furrow method of water application are presented in Table1. The results revealed that yields of all vegetable crops were higher when water was applied through drip irrigation. Maximum yield of 250.0 q ha^{-1} was recorded for drip irrigated tomato. Singh *et al.*, (2009) reported about 55% highest fruit yield of tomato through drip irrigation. In case of drip irrigated vegetables, the

percent increase in the yields over conventional furrow irrigation system was found highest in pea (65.80%) followed by tomato (58.70 %), cauliflower (57.7 %), french bean (39.1 %) and potato (38.2%). The higher yields under drip system can be attributed to optimal soil moisture regime in the crop root zone and reduced nutrient losses. Frequent application of irrigation under drip irrigation systems reduced the water stress to the plants resulting in better yields. Increase in yields of drip irrigated vegetables has also been reported by Imtiyaz et al., 2000, Bhella (1988), Bafna*et al*.,(1993), Elkner and Kaniszewski (1995) and Raina *et al*., (1999). Singh et al., 2005 reported that the potato yield was 588.0 q ha^{-1} with drip irrigation method compared to 507.8 q ha^{-1} with furrow mode of irrigation. These findings are also in agreement with Tagar*et al*., 2012 who reported higher yields of tomato as compared as compared to furrow irrigation systems. The water productivity of all the studied vegetable crops was higher in drip irrigation than furrow method of water application (Table 1). Average WP of all crops under drip and furrow method was 6.89 and 1.31 kg/ m^3, respectively. The highest WP was observed in tomato (13.7 kg m-^{3}) under drip irrigation. Higher yield (18-24%) and water use efficiency (35 - 103 %) of drip over furrow method has also been reported in potatoes (Ibragimov*et al*., 2007).

Table 1: Yield and Water Productivity of Vegetables under Drip and Furrow Methods

Crops	Yield (q ha-^{1})		Percent Yield Increase Over Furrow Method	Water Productivity (kg m^{-3})	
	Drip	Furrow		Drip	Furrow
Tomato	250.0*	157.5	58.7	13.70*	2.86
Potato	186.3*	134.8	38.2	7.94*	1.17
Cauliflower	198.9*	126.1	57.7	8.89*	1.28
French bean	71.2*	51.2	39.1	2.96*	0.83
Pea	52.7*	31.8	65.8	0.97*	0.42

*values are significantly higher at p=0.05

Economic Returns

The gross returns were computed by multiplying average market rate with the yield of respective vegetables during the crop harvesting period. The seasonal gross expenditure, gross return, net return and BC ratio for drip irrigation conventional furrow irrigation system for all the selected crops are depicted in Table 2. The result reveals that for all vegetable crops the net return and CB ratio was higher under drip irrigation than conventional furrow irrigation system. The highest net return per hectare under drip irrigation system was recorded for cauliflower (1,98,336Rs ha^{-1}). Furrow irrigation system consistently underperformed in case of all the vegetables with lowest net returns recorded for french bean Rs13,312 per ha followed by pea (25,203Rs ha^{-1}). Under both the methods of irrigation net return for cauliflower was the highest.

Table 2: Economics of Vegetable Cultivation under Drip and Furrow Method of Irrigation

Crops	Gross Expenditure (Rs ha^{-1})		Gross Return (Rs ha^{-1})		Net Return (Rs ha^{-1})		Gross EWP (Rs m^{-3})	
	Drip	Furrow	Drip	Furrow	Drip	Furrow	Drip	Furrow
Tomato	1,04,642	93,589	2,50,000	1,57,502	1,45,358*	63,912	137.0*	28.6
Potato	1,37,139	1,22,199	2,23,560	1,61,760	86,422*	39,562	119.1*	17.5
Cauliflower	1,00,014	86,514	2,98,350	1,89,150	1,98,336*	1,02,636	88.9*	12.8
French bean	98,614	89,048	1,42,400	1,02,360	43,786*	13,312	59.2*	16.6
Pea	1,26,457	1,01,957	2,10,800	1,27,160	84,343*	25,203	38.8*	16.8

*values are significantly different at p=0.05

The economic analysis revealed that for all the vegetable crops, the BC ratio was found higher under drip irrigation than conventional furrow irrigation system as depicted in Figure 1. In both the methods of irrigation, the BC ratio was found highest in cauliflower (2.98 for drip and 2.19 for furrow). The higher BC ratio proves the economic feasibility and viability of drip irrigation method among the tribal farmers for cultivating vegetable crops. The percentage increase of BC ratio reveals the profit enhancement of vegetable crops by adoption of drip irrigation technology by the farmers. The percentage increase of BC ratio was highest in tomato (41.96 %) among the five crops followed by cauliflower (36.44%), pea (33.66 %) and french bean (25.62 %) (Figure 2). The lowest percentage increase of BC ratio was registered in potato (23.15%). The study indicates that, among all the studied vegetables, tomato cultivation under drip irrigation resulted in higher BC ratio. This implies that higher net benefits per unit of cost incurred can be achieved for tomato cultivation. The results suggest that tomato and cauliflower were the most beneficial crops under drip system.

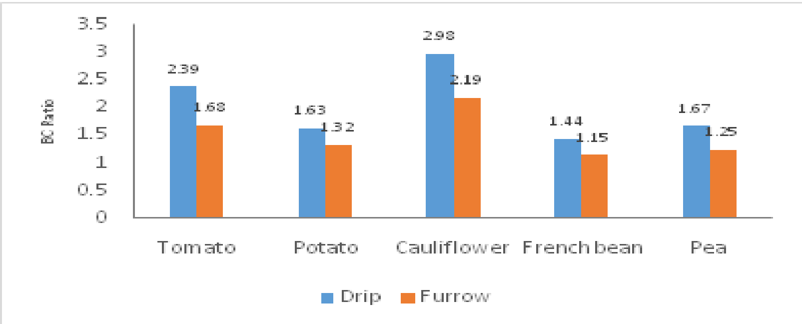

Figure 1: BC Ratio for Vegetable Cultivation Using Drip and Furrow Method

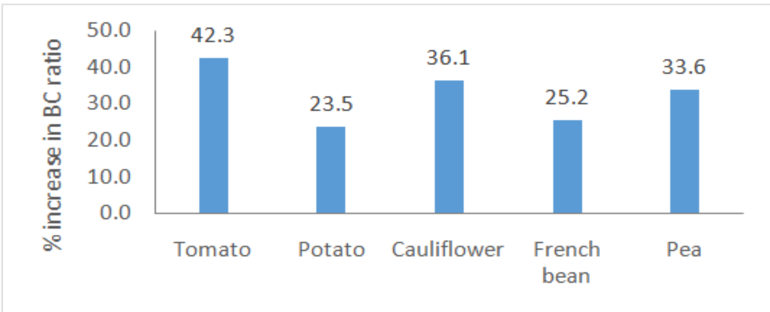

Figure 2: Percentage Increase of BC Ratio of Vegetable Cultivation under Drip over Furrow Method

Economic Water Productivity

The economic water productivity (EWP) was positively related with WP. As observed in case of WP, the EWP of vegetables cultivated with drip irrigation was significantly higher over furrow method of irrigation. The efficient water can be used by drip irrigation technique and frequently water can be applied. Water loss through runoff and evapotranspiration was much lower from soil surface under drip irrigation. It increases the water use efficiency as compared to surface irrigation. Singh et al. (2009) also reported about the higher WP of vegetable crop under drip irrigation technique. The scatter plot of relationship between WP and EWP of vegetables under Drip and furrow method is shown in Figure 3. If we divide the chart in four quadrants, tomato lies in the high EWP and high WP region in case of drip method. Tomato has low WP and low EWP under furrow method. This is mainly because of reduced yields of tomato under this method. For all the selected crops the WP and EWP lies in the quadrant that is characterized with low WP and low EWP. Tomato, potato and cauliflower were identified as best performers with drip irrigation in farmers' field and farmers, management practices.

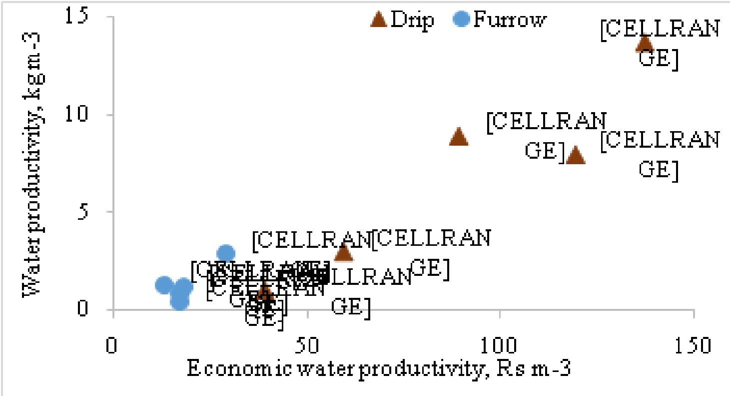

Figure 3: Relationship between WP and EWP of Vegetables under Drip and Furrow Methods

Drip irrigation performed well in farmers' field conditions. All the participating tribal farmers were convinced with the drip irrigation system. Involvement of farmers in the estimation of net returns lead to in-depth understanding of the farmers on potential benefits of the system. The prior trainings and hands-on-experience on drip system were useful as entry point activity in large scale spread of this technology. Such demonstrations and participatory evaluation will be very useful the state governments and other line departments working on popularization of drip system among the farmers of eastern plateau and hill region. There are some disadvantages inherent with drip irrigation technology such as high material and installation cost, emitter clogging, periodical maintenance and skilled operation. However, these can be easily tackled by providing training and hands-on-experience type of capacity building programs in participatory mode. Incentives in the form of subsidy on irrigation system, fertilizer and mulching material can lead large scale adoption of this effective technology in the region. Apart from demonstrating the effectiveness of technology in the field, developing the confidence among the farmers that they can also operate and maintain drip system is the key factor in popularization and large scale adoption of drip irrigation system.

CONCLUSIONS

Irrigation of vegetable using drip system increased the yields from 38 to 65 %. Increased efficiency of water application in combination with increased yields, increased the WP of vegetable production under drip system. Increased reduced cost of labor in irrigation, fertilizer application and weeding combined with increased economic returns lead to higher EWP of vegetable production under drip system. Apparently, one can assume that all vegetable crops can do well under drip system and give good returns. However, as observed in this study there are some crops (pea and french bean) which performed well under drip system but their performance was far low as compared to tomato, potato and cauliflower. This highlights the need for comparative evaluation of crops under drip systems in the farmers' fields. The BC analysis of drip and furrow irrigated vegetables was beneficial in demonstrating and convincing the farmers for adoption of drip irrigation systems. Such type of study can be helpful in framing guidelines for crop selection and influence farming community to adopt drip irrigation technology instead of traditional furrow.

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